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DIAMOND DRILLING BLAST HOLES, BELLEFONTE MINE, NATIONAL GYPSUM CO., CENTRE COUNTY, PA.[1]

By McHenry Mosier[2]

SUMMARY

The principal advantages of drilling blast holes in stopes at the Bellefonte mine are increased safety for the workmen and greater efficiency in breaking ground.

Beds of high-calcium limestone are mined by shrinkage stoping. The limestone is hauled by electric trains from the stopes to an underground crusher, thence conveyed by belts to surface for calcining. Diamond drills operating in slots at either end of 300-foot stopes put in horizontal slabbing holes 140 feet in length. This has increased stoping efficiency with respect to tons broken per pound of powder, tons broken per foot drilled, feet drilled per machine-shift, tons broken per man-shift, and tons broken per machine-shift. Two men are employed on each diamond drill as against one man on a percussion drill in stopes.

Complete bit records were not available at the time of the author's visit, but the partial record is indicative of trends. The diamond bit-replacement cost for 7 bits which drilled 14,228 feet was $0.0112 per foot drilled. The diamond loss on 8 bits which drilled 31,280 feet was 0.0012 carat per foot drilled. The average footage for 14 bits which drilled 45,836 feet was 3,274 feet per bit, while the minimum was 165 feet and the maximum 7,326 feet per bit.

INTRODUCTION

This paper is one of a series recently undertaken by the Mining Division of the Bureau of Mines, Lowell B. Moon, chief, to describe current practice in diamond drilling for production at various mines throughout the United States and to discuss the relative merits of this method compared with drilling by percussion rock drills.

The Bureau of Mines and the mining companies that are cooperating with it in this investigation have the objective of developing information on

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1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7438."

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diamond-drilling blast holes for the benefit of all who are interested in the possible improvement of mining operations.

The National Gypsum Co. acquired its underground limestone mine at Bellefonte, Centre County, Pa., in 1941. The output of crude limestone last year was 457,000 short tons.

The operating data in this paper were furnished to the author by Keith W. Waugh, works manager, and his technical staff in April 1947.

GEOLOGY AND MINERAL DRESSING

Beds of high-grade limestone 55 to 70 feet thick dip 70° to 80°.

The crude stone at the Bellefonte mine carries a minimum of 97 percent $CaCO_3$ and averages 98 percent. It is calcined to a high-calcium lime for the chemical industry and for metallurgical flux. Other products are hydrate of lime for the chemical, agricultural, and construction industries, limestone flour for coal-mine dusting and agricultural uses, stone for glass manufacture, and animal-feed filler. The carbon dioxide loss in calcining the crude limestone is 44 percent by weight.

MINING METHOD

The mine was opened by an 18° inclined shaft, which intersected the ledge at a right angle at a vertical depth of 330 feet. This slope accommodates (1) a 30-inch belt for conveying crushed limestone to surface, (2) a car for transporting men and supplies and (3) pump and compressed-air columns.

A haulage drift was driven in the ledge along the footwall, to serve shrinkage stopes which were laid out in blocks 300 feet long, separated by 40-foot pillars. The width of the stope is the width of the ledge. From the haulage drift a raise for a manway was run on the center line of each pillar along the footwall, and under the stopes chutes were raised 30 feet to connect at 60-foot intervals with a grizzly drift driven in the ledge, 20 feet from the footwall. Grizzlies with 10-inch openings were installed on the footwall over these chute raises. From each grizzly, two fingers were inclined toward the hanging wall and belled to connect with the sill of the shrinkage stope which is 25 feet above the grizzly level.

The shrinkage stope is silled with percussion drills, horizontally from the footwall to a width of about 36 feet and to a height of 12 feet. The sill is then extended to the full width of the stope (70 feet maximum) by slabbing with diamond drills, but the floor is inclined upward at 30°.

A 12- by 12-foot slot is next cut at each end of the stope along the pillar line across the entire width from foot wall to hanging wall, using percussion drills. From this slot, parallel, horizontal holes in a single row with a 12-foot burden are diamond-drilled at 11-foot intervals to a depth of 140 feet. In some instances, an extra relief hole is required at both hanging wall and foot wall. A slot at each end of the stope is

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preferable to a single slot across the centre of the stope because drill stations are more accessible, more diamond drills can operate simultaneously, and shooting against the solid is obviated.

Entrance to shrinkage stopes is through sublevel drifts driven from pillar raises at 25-foot intervals. These raises are single-compartment 6- by 6-feet in cross section, in which steel ladders are fastened to the footwall by split bolts threaded through pipe nipples to provide toe room beneath the rungs. Plans are under consideration whereby pillar raises will not be necessary. Under this proposal a raise drilled down the stope center by diamond drills and shot in sections will connect the shrinkage sill with the supply and ventilation level above the stope. The slot across the width of the stope can then be made by slabbing into the raise with diamond drills. Upon completion of the slot, the stope can be slabbed by parallel rows of holes. By this method pillar raises and sublevel drifts for entrance to stopes are eliminated.

The present stoping lift ranges from 150 to 190 feet.

Semigelatin dynamite with a strength of 60 percent, in 1.25- by 8-inch cartridges, is used in development headings and in long holes in stopes. The latter are loaded to the collar. The primer, which is placed near the middle of the charge, is detonated with a single No. 6 electric blasting cap, zero delay. Semigelatin dynamite with a strength of 40 percent is used in finger raises, stope development, and slots. It is fired with safety fuse and No. 6 blasting caps.

Underground trains of 10 5-ton, Granby-type cars are pulled by 8-ton, storage-battery locomotives. The 36-gage track is laid with 60-pound rails. Cars are loaded from stope chutes with an opening 54 inches wide and 40 inches high. The chute doors are plank, with tail-board control. Cars are dumped into a pocket at the foot of the incline from surface, where the stone is fed into a 16-inch gyratory which crushes to a 4-inch size. A belt conveyor installed in the incline delivers the crushed stone to surface.

DIAMOND DRILLING

Diamond-drilling blast holes was started at the Bellefonte mine in December 1945. Diamond drills are used for breaking ground in shrinkage stopes where horizontal holes are drilled to a depth of 140 feet. The diamond-drill crew, which comprises an operator and a helper for each machine, are paid a straight daily wage.

Equipment

Four drills with the specifications as follows are operating two shifts a day.

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Item	Drill A	Drill B
Number in operation	1	3
Air motor:		
Type	Rotary	Rotary
Horsepower at 80 pounds air pressure	5	10
Feed:		
Type	Screw	Screw
Run (length in inches)	24	27
Revolutions per inch of bit advance	100- 800	100-1,200
Bit speed (range, r.p.m.)	0-1,500	0-3,300
Weight of drill (pounds)	160	155
Capacity (EX rods - feet)	500	500

"E" rods in 5-foot sections are used exclusively. Rod pullers are not necessary on these horizontal holes. Cast-set and sintered, concave plug and pilot types of bit are used, with first-quality stones in EX and LM sizes. EX bits range from 8 to 14 carats and contain 100 to 125 stones. An EX bit drills a hole approximately 1.5 inches in diameter, while an LM bit drills a hole 1/16-inch smaller in diameter. Both plug and pilot bits show small deviation in alinement of hole in a length of 140 feet.

Four loading long holes, a wooden tamping stick 1 inch in diameter, in 5-foot sections joined with an interlocking brass hook, is in satisfactory use.

Set-Up

Each diamond-drill machine is mounted on a 3.5-inch, single-screw column 6.5 feet in length. One machine operates in each transverse slot in the stope. Either a 2-foot core barrel or an adapter is used between the bit and the rod. To reduce the noise level, a muffler with 12 feet of 1.25-inch hose is attached to the exhaust of each machine. Air pressure is 100 to 105 pounds per square inch at the compressor and about 90 pounds at the machine.

PERCUSSION DRILLING

All percussion drilling was done with detachable bits, except that done with stopers, which employed 1-inch hexagonal, hollow, conventional steel. The stoper starters were 1-3/4 inches in diameter and the gage change on an 18-inch run was 1/16-inch. All other drilling was done with detachable bits with 1/8-inch gage change, starting with a diameter of 2-1/8 inches.

In haulage headings, two 3-1/2-inch drifters using 1-1/4-inch, hollow, round steel were mounted on a 3-1/2-inch by 10-foot single-screw column. In cross section, these drifts were 14 feet wide and 10 feet high. The round comprises 26 9-foot holes. The charge was 110 pounds of 60-percent dynamite. Mucking is done with a 60-inch scraper, pulled by a three-drum electric slusher hoist on a 440-volt d.c. circuit. In grizzly drifts, one 3-inch drifter, using 1-1/8-inch, hollow, round steel, drilled a 6-foot round of 17 holes. The cut was a single, 40-inch hole, around which the 6-foot holes were staggered in expanding circles.

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RESULTS OF DRILLING

Operating data on both diamond drilling and percussion drilling in stopes are given in table 1. This shows that diamond-drilling blast holes in stopes has increased stoping efficiency with respect to (1) tons broken per pound of dynamite, (2) tons broken per foot drilled, (3) feet drilled per machine-shift, (4) tons broken per man-shift, and (5) tons broken per machine-shift.

The only decrease is in feet drilled per man-shift, which is due to the employment of two men on each diamond drill as against one man on a percussion drill in stopes.

In table 1, to insure a true comparison of the two types of drilling, the data on percussion drilling during a 5-month period ended January 31, 1946, were taken as representative of stoping by percussion drilling and the calendar year 1946 of stoping by diamond drilling. The current performance of percussion drilling would not give an accurate basis of comparison, because this type of drilling in stopes is limited to the more difficult work of cutting slots.

TABLE 1. - Operating data on stope drilling

	9/1/45 to 1/31/46, stoping with percussion drills	Calendar year 1946		
		Stoping with diamond drills	Slotting with percussion drills	Combined stope drilling
Man-shifts, stoping	725	1,583	1,613	3,196
Hole drilled, feet	38,658	59,738	70,967	130,705
Dynamite, pounds	20,797	35,618	41,032	76,650
Stone broken, tons	43,244	323,619	68,046	391,665
Stone broken/lb. of dynamite, tons	1/2.08	9.09	1.66	5.11
Stone broken/ft. drilled, tons	1/1.12	5.42	0.96	3.00
Distance drilled/man-shift, feet	1/53.28	37.76	44.00	40.88
Distance drilled/machine-shift, feet	1/53.28	75.52	44.00	61.36
Stone broken/man-shift, tons	1/59.60	204.40	42.16	122.48
Stone broken/machine-shift, tons	1/59.60	408.80	42.16	183.76
Remarks	1 man/ drill	2 men/ drill	1 man/ drill	3 men/ 2 drills

1/ Waugh, Keith W. Percussion Versus Diamond Drills at National Gypsum's Bellefonte Mine: Pit and Quarry, vol. 39, No. 6, December 1946.

Any fraction of a shift on drilling was counted a full shift, although it may have included travel time, barring down the roof, levelling or mucking out the drill station, laying pipe lines, setting up the drill, loading holes, and other related jobs.

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MERITS OF DIAMOND-DRILLING BLAST HOLES AT BELLEFONTE MINE COMPARED TO PERCUSSION DRILLING

The advantages of diamond-drilling blast holes in stopes at the Bellefonte mine are:

(1) Increased safety for workmen because work is confined to slots and exposure to hazards of wide roof spans is eliminated.

(2) Less barring down of the roof is required because work is limited to drill stations in slots.

(3) Better fragmentation.

(4) Smaller consumption of powder.

(5) Greater stoping efficiency.

(6) Less drill-maintenance cost.

The disadvantages are:

(1) More skill required to load and blast long holes.

(2) Drilling operations cannot be completely standardized because percussion drilling is essential in much of the mine work, particularly in development headings.

CONCLUSIONS

A notable economy in breaking ground has been achieved at the Bellefont limestone mine of the National Gypsum Co. by diamond-drilling blast holes in stopes.

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